U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB80-115991

Light-Duty Diesel Gaseous Emissions Measurement Comparison of Dilution Tunnel Test Results to Certification Cell Test Results

(U.S.) Environmental Protection Agency, Ann Arbor, MI

Jan 79

SDSB 79-04

PB80-115991

Technical Report

January, 1979

Light-Duty Diesel Gaseous Emissions Measurement - Comparison of Dilution Tunnel Test Results to Certification Cell Test Results

by

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Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air, Noise and Radiation
U.S. Environmental Protection Agency

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NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
SDSB 79-04		

4. TITLE AND SUBTITLE
Light duty diesel gaseous emissions measurement - comparison of dilution tunnel test results to certification cell test results.

5. REPORT DATE
January 1979

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Alson, Jeff

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Standards Development & Support Branch
Office of Mobile Source Air Pollution Control
U.S. Environmental Protection Agency
Ann Arbor, MI 48105

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report summarizes gaseous emissions data for eleven light-duty diesel vehicles using both the standard certification test procedure and the dilution tunnel test procedure which incorporates particulate measurement. The greatest variability was found in the HC variability inherent in measuring HC and, in the extreme cases, also to equipment inconsistencies between the test cells. CO, NOx and CO_2 data from the dilution tunnel test procedure were generally in good agreement with the certification data withthe only trend being slightly lower NOx and CO_2 values from the dilution tunnel. This is hypothesized as a possible dynamometer effect. It is concluded that there are no significant differences in the two test procedures with regards to the measurement of gaseous emissions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Diesel engines Emission Motor vehicles Tests Nitrogen oxide Hydrocarbons Carbon monoxide Carbon dioxide	Certification Particulate measurement	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Unlimited	Unclassified	13p
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE A02-A01

EPA Form 2220-1 (9-73)

Abstract

This report summarizes gaseous emissions data for eleven light-duty diesel vehicles using both the standard certification test procedure and the dilution tunnel test procedure which incorporates particulate measurement. The greatest variability was found in the HC measurements. This is partially attributed to the variability inherent in measuring HC and, in the extreme cases, also to equipment inconsistencies between the test cells. CO, NOx, and CO_2 data from the dilution tunnel test procedure were generally in good agreement with the certification data with the only trend being slightly lower NOx and CO_2 values from the dilution tunnel. This is hypothesized as a possible dynamometer effect. It is concluded that there are no significant differences in the two test procedures with regards to the measurement of gaseous emissions.

Introduction

During the past six months eleven light-duty diesel vehicles have been tested for gaseous emissions using the light-duty diesel test procedure which has been developed to facilitate particulate measurement. This testing was conducted as the final phase of the light-duty diesel particulate baseline study. Emissions test results have also been obtained for these vehicles using the current light-duty diesel certification test procedure. A direct comparison can be made between the proposed test procedure and the present certification procedure regarding the measurement of gaseous pollutants. Obviously the viability of the new test procedure will rest heavily on its ability to closely duplicate the results of the present certification system. This report will assess the ability of the new test procedure to do this.

Test Procedure

The certification emissions test results were obtained according to the procedure outlined in the Federal Register and the tests were performed in light-duty diesel certification test cells 5 and 6. The new test procedure was described in the "Draft Test Procedure for Measurement of Gaseous and Particulate Emissions from Light-Duty Diesel Vehicles," September, 1978, and was implemented in test cell 508. With regards to gaseous pollutants the only major difference between the procedures is that the new one incorporates a dilution tunnel rather than a large baffle box as the mixing medium. Henceforth, the new test procedure will be referred to as the dilution tunnel system.

Results

The results of the dilution tunnel-certification comparison

are given in Tables I and II and in Graphs I through IV. Table I gives the actual HC, CO, NOx, CO_2, and fuel economy data for the eleven vehicles tested by both the dilution tunnel and certification test procedures. Both Federal Test Procedure (FTP) and Highway Fuel Economy (HWFE) tests were conducted. Table II presents the same data with the difference between the dilution tunnel and certification values expressed as a percentage of the latter. It also gives recent Repca (correlation vehicle) values which are indications of the variability present among the various test cells at EPA at this time. It should be noted, however, that Repca is a gasoline-fueled vehicle which limits its applicability with regards to diesel test cells.

Graphs I, II, III, and IV give a Cartesian presentation of the same data for each pollutant. The X's represent data from the HWFE tests and the solid points represent FTP data. Each graph shows the "ideal" fit which would result from perfect duplicity of the data from the two test procedures, as well as the "best" fit (least-squares regression) lines for both the FTP and HWFE data. In addition, Graph I includes the "best" fit lines for HC excluding the one pair of data from the Peugeot 504D which greatly deviates from the rest of the HC data.

Analysis of Results

As is often the case with diesel vehicles, and which is indicated in Table II, HC was the pollutant most sensitive to the change in test cells. The trend was most pronounced in the HWFE data with nine of the eleven vehicles registering relative differences of 8.6 percent or more but was also evident in the FTP data where seven vehicles experienced differences of 7.3 percent or more.

There are several factors which help to explain or ameliorate this apparent problem, however. The first is the fairly large Repca value of 14 percent which indicates the inherent variability problems with HC measurements. Admittedly, Repca is a gasoline-fueled vehicle but the same variability problems with regards to diesel HC and the heated flame ionization detector (HFID) are well known. Assuming the Repca number to be some measure of statistical acceptability, we find that just three of the relative FTP values and four of the relative HWFE values exceed this figure.

A second factor to be considered is the general scatter of the FTP data about the ideal fit line as shown in Graph I. Except for the Peugeot, Mercedes, and International Scout vehicles (the highest and two lowest FTP values), the FTP data all lies very close to the ideal fit line with no trend indicated. This latter fact indicates that the effect, if any, of the dilution tunnel upon the majority of HC measurements is a random one.

As mentioned above and indicated in Table II, the Peugeot, Mercedes, and International Scout vehicles experienced the greatest relative HC differences. The latter two were the lowest HC emitters with concentrations in the 0.3 gram per mile (gpm) range over the FTP. The high relative values for these two vehicles are clearly due in part to their small absolute magnitudes. The Mercedes, for instance, experienced a 0.05 gpm difference between the two test procedures. This doesn't appear to be a problem until it is realized that it represents a 16.7 percent relative change. Thus the small magnitudes of the values contribute to the apparent correlation problem.

Still, the absolute differences of 0.05 and 0.09 gpm for the Mercedes and Scout vehicles have another possible explanation. The HFID HC analyzers in the certification test cells utilize only one range (0 to 100 ppm HC) for all HC measurements. The HFID analyzer in the dilution tunnel test cell utilizes three different ranges (0 to 100, 0 to 50, 0 to 25 ppm HC), the lowest of which allows much greater sensitivity as compared to the certification range. Thus when testing cars with fairly high HC emissions the same ranges were used for both the dilution tunnel and certification tests. But when testing low emitters like the Mercedes and Scout vehicles the lowest, most sensitive range was used in the dilution tunnel test cell while the higher range was still used in the certification test cells. To further compound the problem all background HC readings in the certification test cells were taken at the higher range while all such readings in the dilution tunnel test cell were taken from the most sensitive scale. Thus this factor may explain why the Mercedes and Scout vehicles had greater absolute HC differences than most vehicles which emitted far more HC. This could also account for the wider differences in the HWFE data base since most of it is clustered around the 0.2 to 0.3 gpm range, where the dilution tunnel analyzer was set as its most sensitive scale.

The most baffling HC data are those of the Peugeot vehicle. The dilution tunnel measurements were 0.22 and 0.47 gpm less than the certification measurements for the FTP and HWFE tests and 20 and 69 percent less on a relative basis. These data have such an effect on the least-squares regression technique (since they are the highest values) that Graph I includes regression lines excluding the Peugeot data.

One possible explanation has been suggested. Peugeot vehicles are certified using a special high volume cooling fan which has a much larger capacity than the standard certification cooling fan. Thus the Peugeot certification results were taken using the high volume fan. When tested in the dilution tunnel test cell, however, the standard cooling fan was used. The effects, if any, of the special cooling fan have not been quantified. One possibility is that the higher volume fan results in a decrease of the coolant

temperature which accordingly decreases the combustion chamber surface temperatures. Lower combustion chamber surface temperatures are known to increase HC and CO emissions due to a larger quenching zone and the resultant increase in incomplete combustion. NOx, on the other hand, would be expected to be lower due to the greater heat losses to the cylinder walls resulting in lower peak temperatures in the cylinders. The data in Tables I and II support this theory completely as the certification cell using the high volume fan recorded higher HC and CO values and lower NOx emissions. As further support of this theory it should be noted that the Peugeot was the only vehicle to have lower FTP NOx emissions in the certification test cell. Thus it is likely that much of the HC differences for the Peugeot can be attributed to the difference in cooling fans.

As Tables I and II and Graphs II, III, and IV indicate, there do not seem to be any significant problems in sampling CO, NOx, or CO_2 with the dilution tunnel test procedure. The CO values were in very good agreement, especially in view of the 11% Repca number indicating the variability among EPA test cells in measuring CO. As Graph II indicates, the FTP data was well scattered about the ideal fit line showing no trend whatsoever. The HWFE data from the dilution tunnel did prove to be somewhat lower, but this doesn't seem to be a serious concern at this time.

The NOx relative values were generally within the Repca value of nine percent as well. The dilution tunnel FTP values were consistently lower than the certification values (except for the Peugeot discussed earlier) while the HWFE values were more scattered. The CO_2 relative values were rarely much greater than five percent although they were often greater than the Repca value of three percent. As with NOx, there was a clear indication that the dilution tunnel test cell measured slightly lower CO_2 emissions. This combination of lower NOx and CO_2 emissions points to a possible dynamometer effect since these two pollutants are most affected by dynamometer-road load considerations. As noted earlier there were no clear trends with regards to higher or lower HC or CO measurements from the dilution tunnel. This latter fact, along with the lack of constant differences in the NOx and CO_2 data, makes it unlikely that a CVS problem was a factor.

Conclusion

Based on the above results and discussion and the realization of the variability inherent in emissions testing, it is concluded that there are no significant differences between gaseous emissions measurements made with the dilution tunnel test procedure and those made using the current light-duty diesel certification test procedure.

TABLE 1

LIGHT-DUTY DIESEL COMPARISON OF DILUTION TUNNEL TEST RESULTS TO CERTIFICATION CELL TEST RESULTS

Vehicle & ID	Total HC ~gm/mi		CO ~gm/mi		NOx ~gm/mi		CO_2 ~gm/mi		Fuel Economy mpg		Cycle
	Dilution Tunnel*	Cert Cell**	Dilution Tunnel*	Cert Cell**	Dilution Tunnel*	Cert Cell**	Dilution Tunnel*	Cert Cell**	Dilution Tunnel*	Cert Cell**	
Oldsmobile 350 9311127 '79 Cert Vehicle	0.59 0.32	0.55 0.35	1.51 0.92	1.60 1.00	1.49 1.20	1.63 1.28	458 334	486 362	22.1 30.3	20.8 27.9	FTP HWFE
Oldsmobile 260 9311F149 '79 Cert Vehicle	0.58 0.20	0.53 0.24	1.35 0.75	1.32 0.78	1.67 1.48	1.84 1.54	409 312	459 329	24.6 32.9	22.0 30.7	FTP HWFE
Oldsmobile 260 9311F-84482F '79 F E Vehicle	0.60 0.22	0.61 0.27	1.49 0.89	1.52 0.92	1.56 1.24	1.58 1.28	412 304	422 315	24.4 33.2	23.9 32.1	FTP HWFE
Oldsmobile 260 9311F181 '79 Cert Vehicle (5 spd)	0.69 0.19	0.66 0.21	1.91 0.72	1.90 0.73	1.62 1.22	1.73 1.76	391 270	396 283	25.7 37.5	25.4 35.7	FTP HWFE
Chev. Pickup 350 9TJ9-168F '79 Cert Vehicle (2-hole injection)	0.78 0.64	0.76 0.57	1.58 1.16	1.63 1.28	1.52 1.41	1.52 1.34	501 398	538 427	20.2 25.3	18.7 23.7	FTP HWFE
Dodge Truck B356 '79 Cert Vehicle (4 spd)	0.54 0.35	0.51 0.36	2.61 1.37	2.50 1.47	1.82 1.57	1.86 1.71	469 403	483 443	21.4 25.1	20.6 22.8	FTP HWFE
Mercedes 300D 123.130-12017745 Special Build/Turbo-Charged with EGR	0.2 0.08	0.30 0.14	1.35 0.73	1.41 0.79	1.36 1.25	1.40 1.01	463 363	480 394	21.8 27.9	21.1 25.8	FTP HWFE
Volkswagen Dasher 406 Z 2466 '79 Cert Vehicle (4 spd)	0.52 0.30	0.55 0.37	1.19 0.64	1.21 0.72	0.98 0.78	1.05 0.83	262 198	277 220	38.3 50.9	36.3 45.8	FTP HWFE
Volkswagen Rabbit 406 Z 2465 '79 Cert Vehicle (5 spd)	0.51 0.20	0.55 0.22	1.01 0.41	1.00 0.43	0.87 0.58	0.95 0.65	238 172	246 185	42.4 58.9	40.8 54.6	FTP HWFE
Peugeot 504D*** 622 '79 Cert Vehicle (4 spd)	0.87 0.21	1.09 0.68	1.69 0.69	2.01 0.76	1.16 1.12	1.05 1.03	362 307	361 307	27.3 32.6	27.7 32.8	FTP HWFE
Int'l Harvest Scout 300 '79 Cert Vehicle (4 spd)	0.27 0.16	0.36 0.16	1.40 0.64	1.42 0.58	1.40 1.55	1.43 1.34	407 383	441 367	24.8 26.5	22.9 27.7	FTP HWFE

* Dilution tunnel measurements were made in cell 508.
** Certification measurements were made in cells 5 and 6.
*** Used special high-flow cooling fan for certification testing.

TABLE II

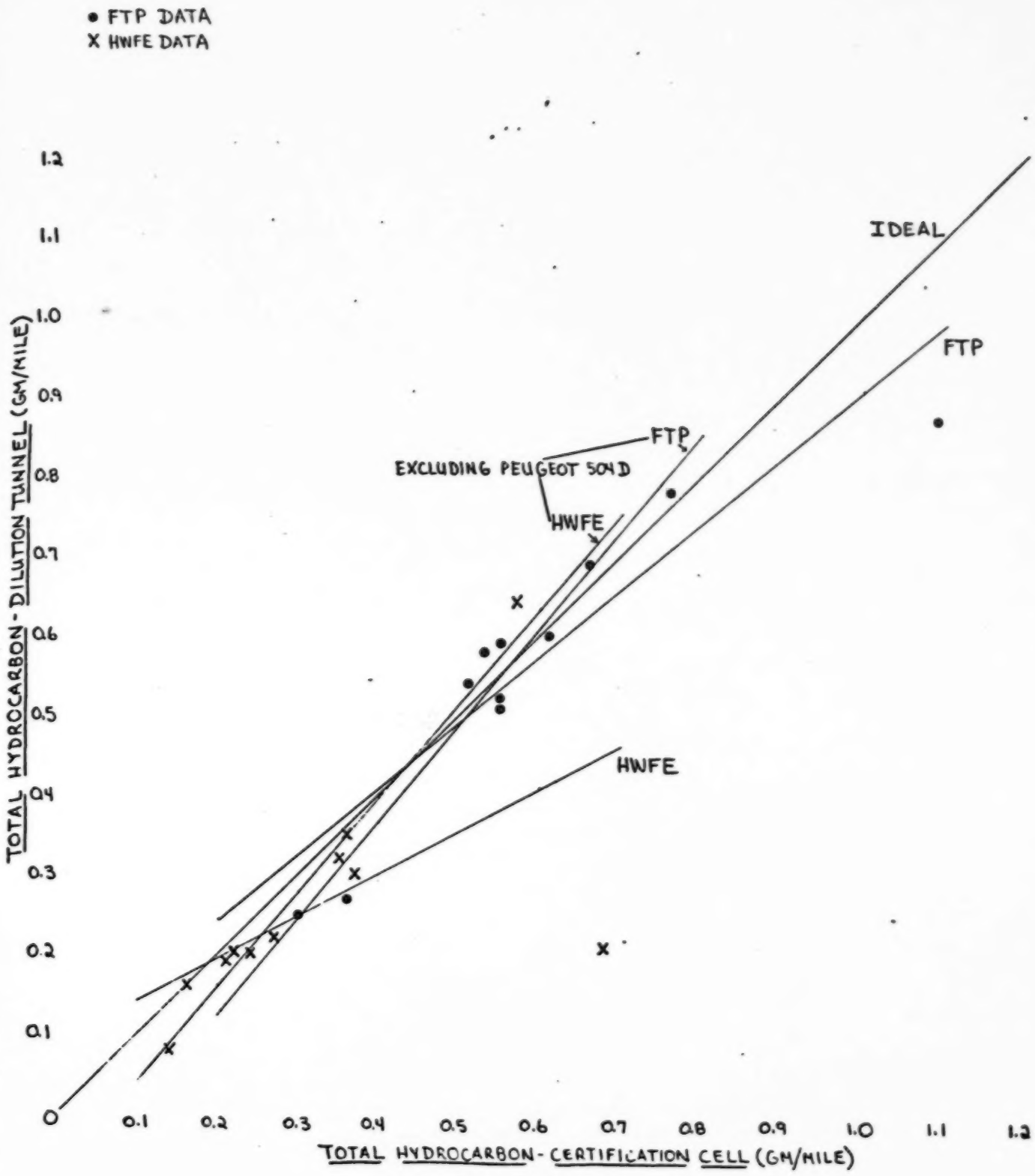
LIGHT DUTY DIESEL COMPARISON OF DILUTION TUNNEL TEST RESULTS TO CERTIFICATION CELL TEST RESULTS

Vehicle & VID	Relative Values* Total HC %	Total CO %	Total NOx %	Total CO_2 %	Fuel Economy %	Cycle
Oldsmobile 350 9JJF127 '79 Cert Vehicle	-7.3 8.6	5.6 8.0	8.6 6.2	5.8 7.7	-6.2 -8.6	FTP HWFE
Oldsmobile 260 9JHF149 '79 Cert Vehicle	-9.4 16.7	-2.3 3.8	9.2 3.9	10.9 5.2	-11.8 -7.2	FTP HWFE
Oldsmobile 260 9JHF-844827 '79 FE Vehicle	1.6 18.5	2.0 3.3	1.3 3.1	2.4 3.5	-2.1 -3.4	FTP HWFE
Oldsmobile 260 9JHF181 '79 Cert Vehicle (5 spd)	-4.6 9.5	-0.5 1.4	6.4 3.2	1.3 4.6	-1.2 -5.0	FTP HWFE
Chevrolet Pickup 9TJ9-168F '79 Cert Vehicle (2-hole injection)	-2.6 -12.3	3.1 9.4	0.0 -5.2	6.9 6.8	-8.0 -6.7	FTP HWFE
Dodge Truck B356 '79 Cert Vehicle (4 spd)	-5.9 2.8	-4.4 6.0	2.2 3.2	4.1 9.0	-3.9 -10.1	FTP HWFE
Mercedes 3000 123.130-12017745 Special Build/Turbo- Charged with EGR	16.7 42.9	4.3 7.6	2.9 -23.8	3.5 7.9	-3.3 -8.1	FTP HWFE
Volkswagen Dasher 406 Z 2466 '79 Cert Vehicle (4 spd)	7.3 9.1	1.6 11.1	6.7 6.0	5.4 10.0	-5.5 -11.1	FTP HWFE
Volkswagen Rabbit 406 Z 2465 '79 Cert Vehicle (5 spd)	7.3 9.1	-1.0 4.6	8.4 10.8	3.2 7.0	-3.9 -7.9	FTP HWFE
Peugeot 504D** 622 '79 Cert Vehicle (4 spd)	20.2 19.1	15.9 9.2	-10.5 -8.7	-0.3 0.0	1.4 0.6	FTP HWFE
Int'l. Harvester Scout 300 '79 Cert Vehicle (4 spd)	25.0 0	1.4 -10.3	2.1 -15.7	7.7 -4.4	-8.3 4.3	FTP HWFE
Repca - one std. dev. as % of mean	14%	11%	9%	3%	3%	FTP

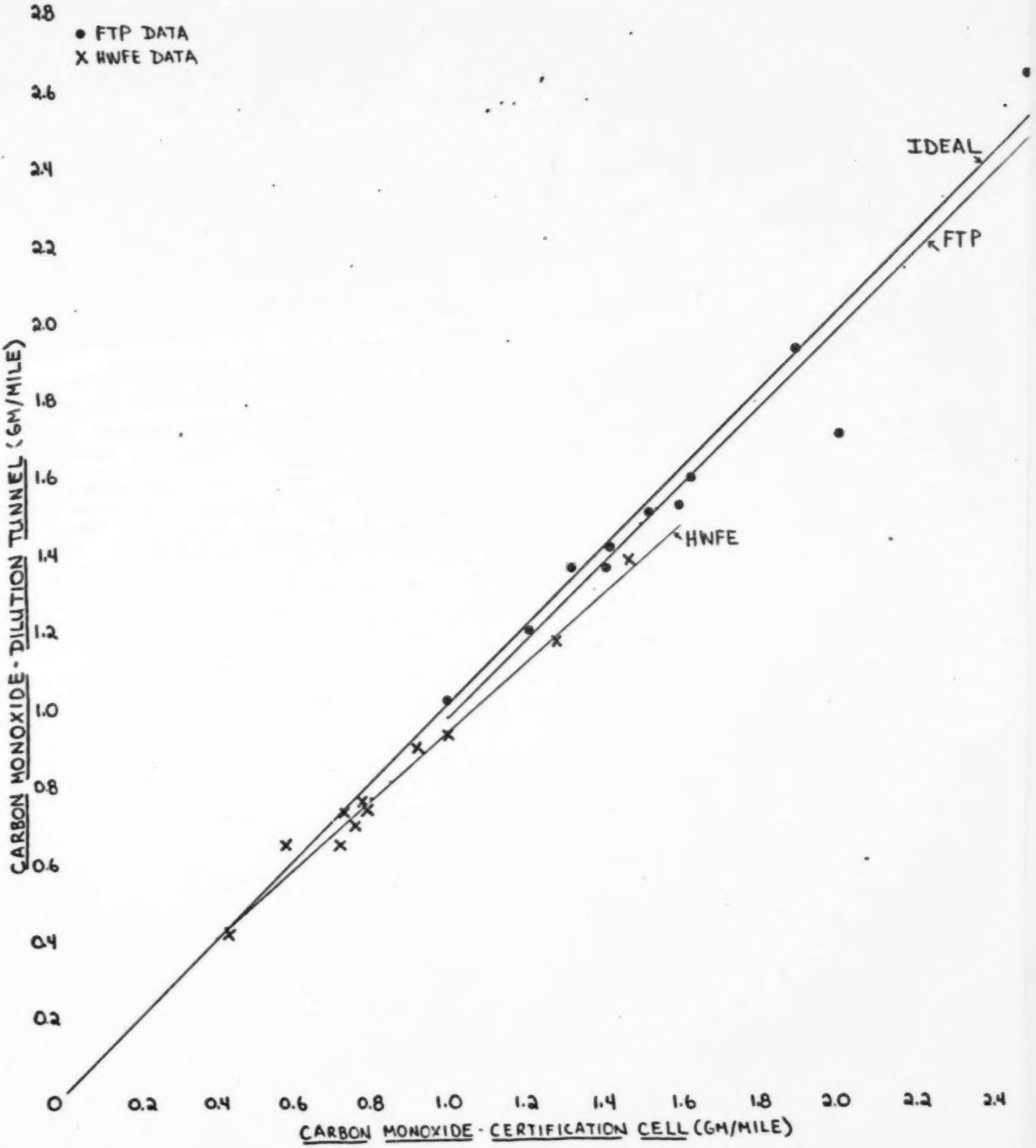
* Relative Value = $\frac{\text{Cert Cell--Dilution Tunnel}}{\text{Cert Cell}}$

** Used special high-flow cooling fan for cert cell testing

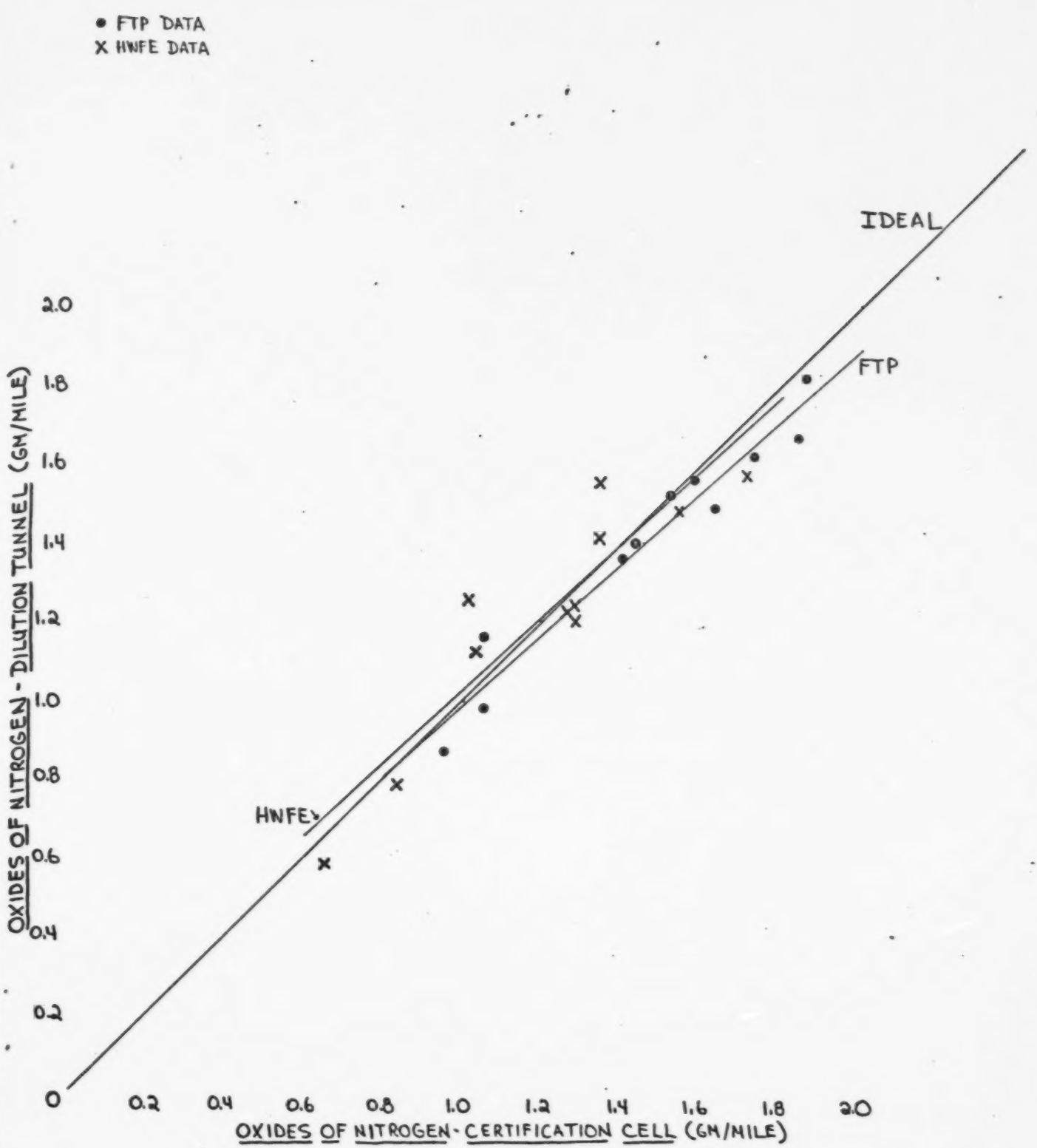
GRAPH I - DILUTION TUNNEL HC vs. CERTIFICATION CELL HC



GRAPH II - DILUTION TUNNEL CO vs. CERTIFICATION CELL CO



GRAPH III - DILUTION TUNNEL NO_x vs. CERTIFICATION CELL NO_x



GRAPH IV - DILUTION TUNNEL CO_2 vs. CERTIFICATION CELL CO_2